Performance Evaluation at the NIST Measurement and Standards Laboratories

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Workshop on Methods to Evaluate Research Outcomes

Committee on Science, Engineering, and Public Policy

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Outline

- Overview of the NIST Planning and Performance Evaluation System
- External Assessment Mechanisms and Peer Review of NIST Laboratories
- Quantitative Metrics and Impact Assessments
- Conclusions: Combining Metrics

NIST is a non-regulatory federal agency within the U.S. Department of Commerce. NIST's primary mission is to promote economic growth by working with industry to develop and apply technology, measurements, and standards. Established by Congress in 1901 as the National Bureau of Standards, it was renamed and assigned new responsibilities in 1988.

NIST carries out its mission through a portfolio of four programs:

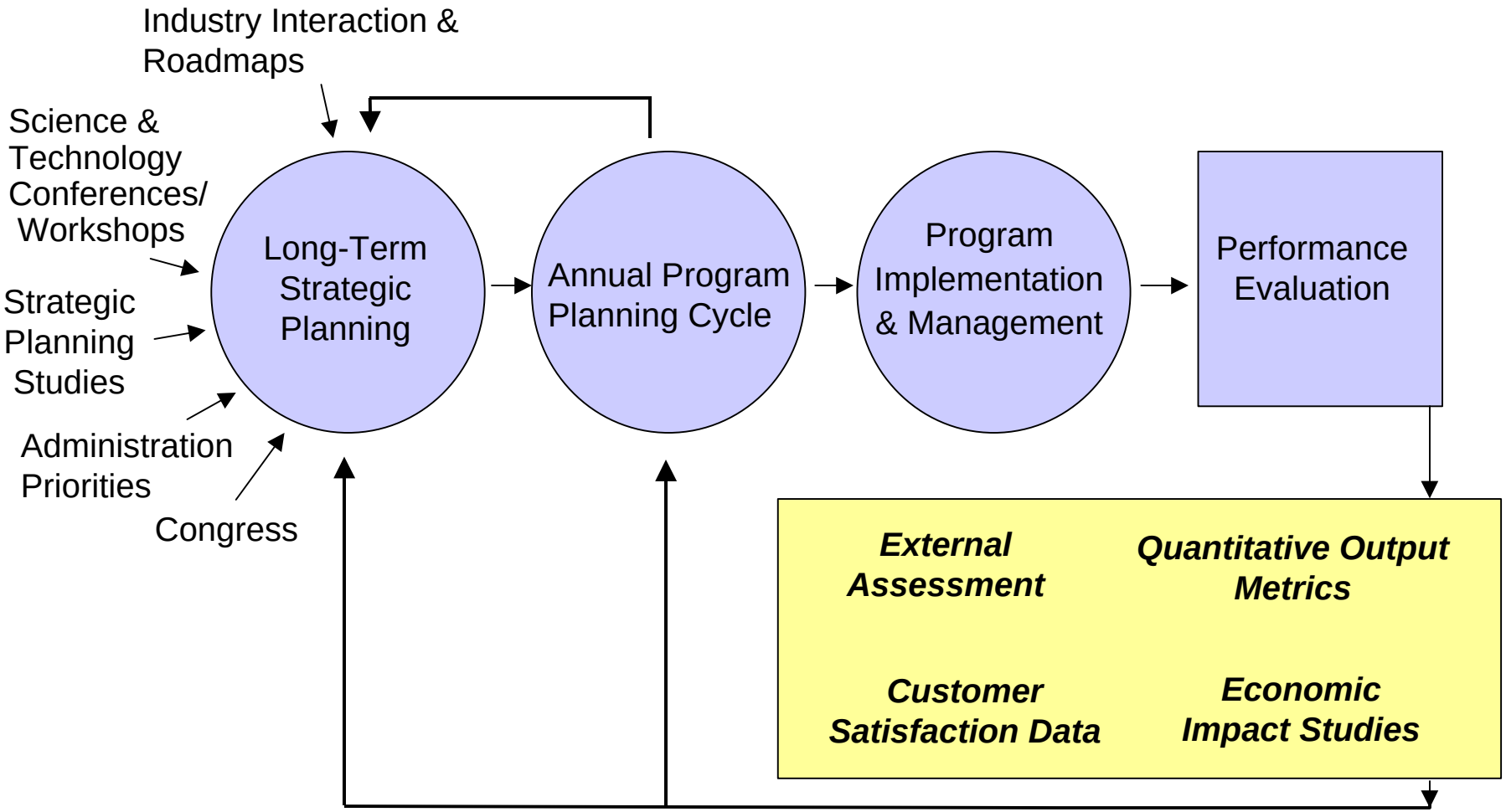
Measurement and Standards Laboratories provides technical leadership for the Nation's measurement and standards infrastructure, and assures the availability of essential reference data and measurement capabilities

Advanced Technology Program stimulates U.S. economic growth by developing high risk and enabling technologies through industry-driven cost-shared partnerships

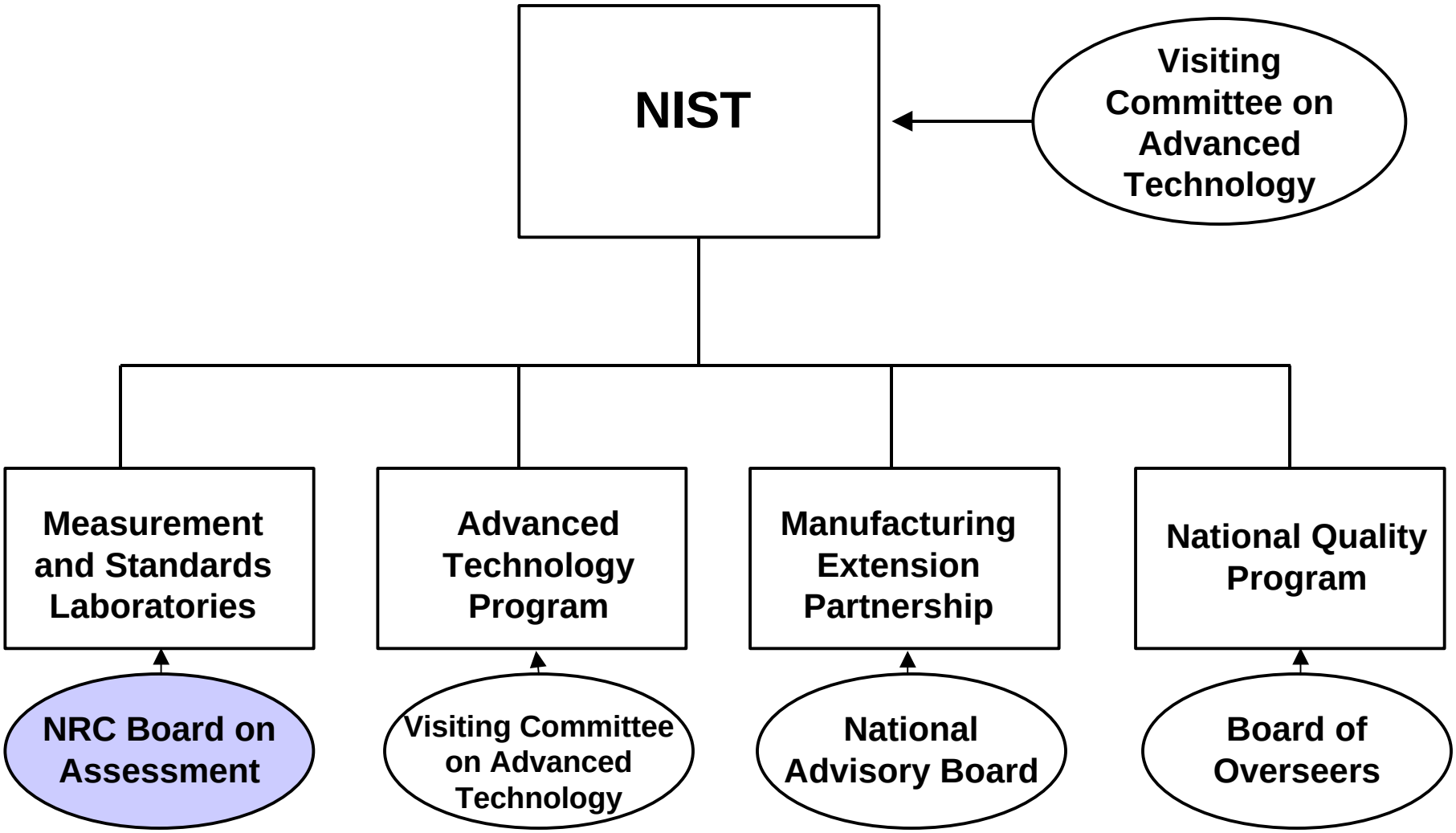
Manufacturing Extension Partnership strengthens the global competitiveness of smaller U.S.-based manufacturing firms by assisting in the adoption of advanced technologies, techniques, and business practices

National Quality Program enhances U.S. competitiveness, quality, and productivity, manages the Malcolm Baldrige National Quality Award, and provides global leadership in promoting quality awareness

Planning and Performance Evaluation at NIST



NIST External Assessment Mechanisms



Laboratory Peer Review: NRC Board on Assessment

- NRC Board on Assessment (est. 1959)
  - 150 leaders from industry, academia, government provide independent expert reviews
  - Organized into 7 panels (one per OU), and 2 subpanels
- Board Selection/Composition
  - NRC controls the selection process
  - NIST advises on and reviews panel membership and composition
  - NRC vets for appropriate composition, quality, and conflict of interest

NRC Peer Review: Scope and Function

Annual NRC reviews focus on **technical quality**:

- The technical merit of the laboratory programs relative to the current state-of-the-art;
- The degree to which the laboratory programs conform to their mission;
- The effectiveness with which the laboratory programs are carried out and the results disseminated; and,
- Insofar as they affect the quality of the technical programs, the adequacy of the laboratories' facilities, equipment, and human resources.

NRC Peer Review: Output and Impact

- **Output**:
  - Annual NRC Report, comprised of panel reports;
  - Briefings for the Visiting Committee for Advanced Technology
- **Impact**:
  - NRC findings/recommendations feed into annual planning and program management
  - NIST response routinely addressed in subsequent year panel reviews

Quantitative Metrics: Laboratory Outputs

Measurement and Standards Laboratories Outputs and Activities

- ◊ Standard Reference Database titles available
- ◊ Standard Reference Materials available
- ◊ NVLAP laboratories accredited
- ◊ NVLAP mutual recognition agreements
- ◊ Patents filed/licenses issued
- ◊ Standards committee participation / chairmanships held
- ◊ International committee participation / chairmanships held
- ◊ Number of technical publications
- ◊ Number of major conferences and workshops
- ◊ Number of requests to central WWW server
- ◊ Number of calibrations and tests performed
- ◊ Standard Reference Material units sold
- ◊ Standard Reference Database units distributed

Economic Impact Studies: Research Outcomes

Purpose: Assess the nature and magnitude of the economic impacts from NIST laboratory research projects.

The measurement challenge: Developing quantifiable, verifiable, cost-effective outcome measures that accurately and comprehensively capture the impact of research over long time periods. **Consider:**

Alternative Refrigerants Research:
Data and Modeling Technologies for Reducing Use of Chloroflurocarbons

Early 1980s	Mid 1980s	Mid to late 1980s	1990s
Research project initiated: characterizing chemical properties of non-CFC refrigerants	*Near term output*: comprehensive and reliable data and analytical models. *Initial outcome*: Accelerates industrial R&D; reduces R&D costs	*Extended outcome*: R&D efficiency gains to refrigerant manufacturers	*Extended outcome*: Heating and cooling equipment manufacturers benefit from downstream R&D efficiencies

Assessing Long-Term Research Outcomes

Radiopharmaceutical Research:
Measurement Technologies for Precision Drug Delivery

Project initiation	Near term output	Long-term impact
1974: Formal program established to develop and deliver to industry standard reference radionuclides	Manufacturers use reference materials to calibrate equipment used to produce radionuclides	*1990s:* Medical applications of radiopharmaceutical therapies increases; social rate of return to underlying research expands

Josephson-Junction Voltage Standard:
Measurement and Calibration Technologies for Electronic Components

Project initiation	Near term output	Long-term impact
1977: New research, design, and development of superconducting integrated-circuit chip used in Josephson junctions	Adaptation of industry fabrication technologies; development of electronic system for Josephson voltage standard; technology transfer to industry	*1990s:* Benefits of precise, rapid voltage measurement extended throughout electronic components industry—manufacturers of Josephson array components and systems; instruments calibrated to the Josephson array; products designed and assessed by calibrated instruments; end-users

NIST Economic Impact Studies: Methods

- Adapt conventional methods and measures used by economists and corporate finance analysts to assess government and corporate R&D.
  - *Research Outputs*: Describe activities and products--measurement and test methods, reference materials, reference data, standards, etc.
  - *Research Outcomes*: Assess impact of NIST infratechnology on manufacturing productivity, R&D efficiency, transaction costs, and related factors at different levels of the supply chain
  - *Net Present Value*: Discount (or inflate) benefit and cost data over a time series to the reference year; subtract present value of costs from present value of benefits.
  - *Benefit-Cost Ratio*: Ratio of discounted benefits to discounted costs.
  - *Social or Internal Rate of Return*: The discount rate that is needed to reduce the time series of net benefits realized by an industry or industries to zero.
  - *Qualitative Impact Tracing*: Document qualitative impact on R&D investment decisions; production and quality strategies; cycle times; etc.

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NIST Economic Impact Studies: Results

Industry: Project	Output	Outcomes	SRR	BCR
Semiconductors: resistivity	Test methods	Increase productivity	SRR: 81%	BCR: 37:1
Semiconductors: thermal conductivity	Materials properties; test methods	Increase R&D efficiency; lower transaction costs	SRR: 63%	BCR: 5:1
Semiconductors: wire bonding	Test methods	Increase productivity; increase R&D efficiency	SRR: 40%	BCR: 12:1
Communications: electromagnetic interference	Test methods	Lower transaction costs	SRR: 266%	BCR:
Automation: real-time control systems	Generic architecture	Increase R&D efficiency	SRR: 49%	BCR:
Photonics: optical fiber	Test methods (acceptance)	lower transaction costs	SRR: 423%	BCR:
Semiconductors: electromigration	Test methods	Increase R&D efficiency transaction costs	SRR: 117%	BCR: 12:1
Energy: electric meter calibration	Test methods (calibration)	Lower transaction costs	SRR: 428%	BCR: 41:1
Communications: ISDN	Interoperability standards	Lower transaction costs	SRR: 156%	BCR:
Computers: software conformance	Test methods (acceptance)	Lower transaction costs	SRR: 41%	BCR:
Photonics: optical instrument	Test method (calibration)	Increase productivity; lower transaction costs	SRR: 145%	BCR: 13:1
Automation: machine tool software error compensation	Quality control algorithm	Increase R&D efficiency increase productivity	SRR: 99%	BCR:118:1
Materials: thermocouples	Reference data (calibration)	lower transaction costs; increase product quality	SRR: 32%	BCR: 3:1
Pharmaceuticals: radiopharmaceuticals	Reference materials	Increase product quality	SRR: 138%	BCR: 97:1
Chemicals: alternative refrigerants	Reference data	Increase R&D efficiency increase productivity	SRR: 433%	BCR: 4:1
Advanced Ceramics: phase equilibria	Reference data	Increase R&D efficiency increase productivity	SRR: 33%	BCR: 10:1

Linking Metrics with Strategic Objectives

- **Goal**: ***Provide technical leadership for the Nation's measurement and standards infrastructure, and assure the availability of essential reference data and measurement capabilities.***
  - **Strategic Objective**: Anticipate and address the Nation's most important needs for physical and information-based measurement and standards.
    - Project example: *Radiopharmaceuticals*
      - **Output**: developed 28 standards for controlling dosage.
      - **Outcomes**: Improved quality of medical diagnostics; benefit-cost ratio of 98:1; social rate of return of 138 percent.
    - Project example: *Alternative Refrigerants*
      - **Output**: developed database of performance characteristics for alternatives to CFCs.
      - **Outcomes**: Increased R&D efficiency; improved equipment productivity; benefit-cost ratio of 4:1; social rate of return of 433 percent

Conclusion: Combine Measures

	Scope & Purpose	Limitations	Validity
Peer Review	Expert assessment of technical quality across OU divisions. Provides essential data for quality control, project management & planning.	Intrinsic to peer review: panel judgments not quantifiable; highly contextual and detailed; not cumulative.	High: NRC independence and high technical capability; internal quality controls.
Quantitative Output Metrics	Variety of indicators of key activities and outputs. Facilitates HR management & resource planning.	Limited data re. quality or impact; requires contextual interpretation; not uniformly applicable across OUs.	High: Direct and verifiable counts of activities and outputs; robust data systems.
Impact Studies of Research Outcomes	Data on downstream impacts of specific research projects & infratechnologies. Provides data for evaluating research outcomes & planning.	Assessment results are intermittent & not cumulative; elements of user population often too diffuse to measure; methodological problems specific to each measure; outcomes specific to each project (limited comparability); expensive.	Moderate to high: Well-developed methods; contracted to highly qualified economists and technical specialists; uneven availability and quality of industry data.